ISSN:2338-5154

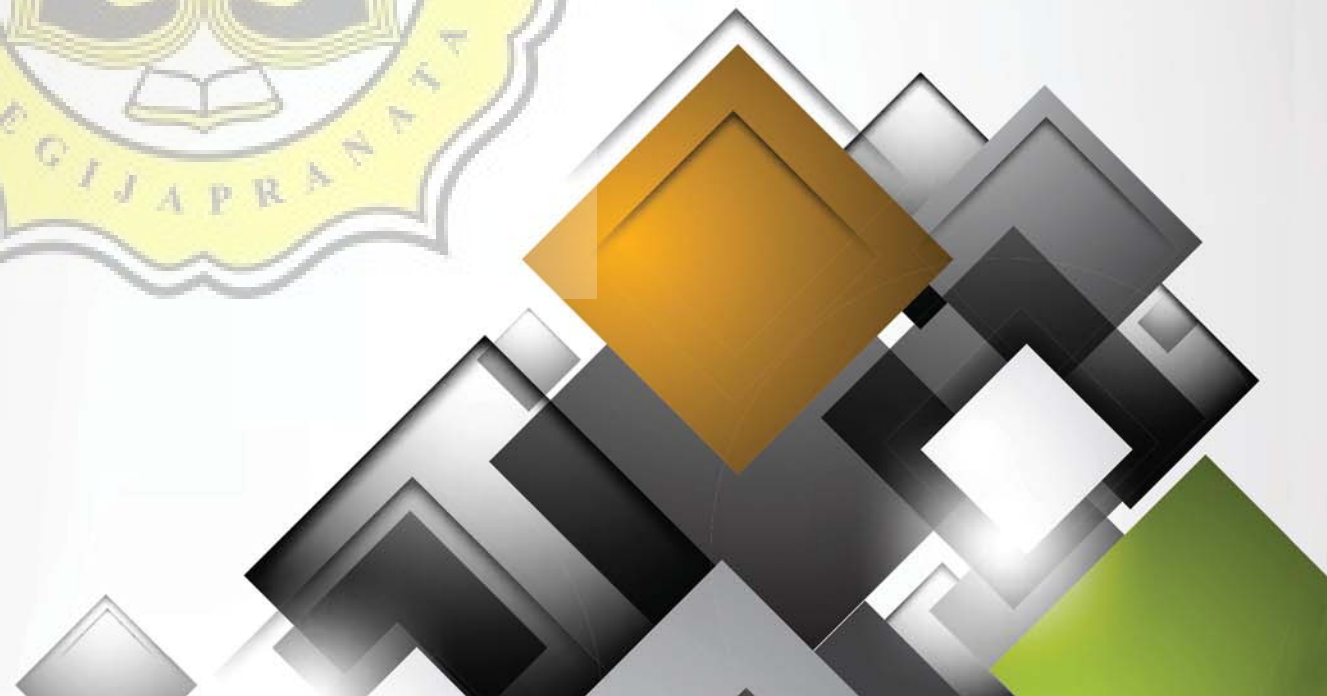
# CITACEE 2013

The 1st Conference on Information Technology, Computer, and Electrical Engineering

Department of Computer Engineering, Diponegoro University

# PROCEEDINGS

"Information technology and Its Application Towards the Implementation of Green Technology"



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**Proceedings**

# The 1st Conference on Information Technology, Computer, and Electrical Engineering (CITACEE 2013)



**Publisher:**
Computer Engineering Department
Diponegoro University

ISSN: 2338-5154

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# Switching Table Based on Space Vector Modulation for Three Phase Inverter using dsPIC

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***Abstract*— This paper describes the concept of Space Vector Modulation (SVM) technique to generate the switching pattern or switching table for three phase inverter topology. The method is used in this modulation technique are take three phase reference signal in a,b,c coordinates and calculate this mathematical equation in *á-β* axist, afterwards transform it to Magnitude-Angle calculation as the basis of vector determination, duty cycle, and switching table generation. The implementation from this project using dsPIC give an advantage in performance and hardware simplicity. Utilization of Lookup Table methods in program algorithms is provide more efficiency in therms of memory and computational process.**

***Keywords- Space Vector Modulation, Inverter, dsPIC, Lookup Table.***

## I. INTRODUCTION

In a wide range application of industrial, transportation, power, renewable energy and other fields, Power Electronics has an important role. The most important of converter topology is inverter. Inverter is used to convert DC (Direct Current) electric waveform to AC (Alternating Current) electric waveform. Inverter control is widely used in the electrical power supply, solar cell/photovoltaic power grid , electrical drive and variable speed drive (VSD) on induction motor[1]..

Inverter topology has been developed and modified, such a the simplest topologies is square wave inverter. With the development of technology, especially in semiconductor. Give influence in the field of control and power electronics device. The development of super fast semiconductor static switching device in the field of power electronic and rapidly improving of control engineering based on digital signal controller and micro process, inverter control techniques is developing too. At first, the inverter is designed by using analog system, the system is quite reliable and reasonably fast response but very susceptible to outside interference (disturbance) and have the complexity on hardware design. Because of these limitations and the times, then the system is becoming obsolete analog and switch to digital systems.

A common methods is used today is scalar control. Scalar control using the magnitude of the voltage, current or flux as a controlled variable . To generate the output voltage can be regulated, generally controlled inverter with Sinusoidal Pulse Width Modulation technique. With this technique the output voltage can not reach the maximum value and generate higher harmonic distortion when compared to the Space Vector Modulation technique. SVM is an algorithm control pulse width modulation for generate switching pattern of inverter topologies in order to produce AC signal with variable amplitude and frequency simultaneously. In addition, by using SVM methods, the hardware to be more compact so it is more practical and economical.

This paper will describe about the method of Space Vector Modulation (SVM) technique to generate the switching pattern or switching table. All of three modulation signal in a,b,c coordinates provide by *Lookup Table* methods, it is used to minimize the computation process that is handled by dsPIC. Programming algorithm in dsPIC include array pointer of lookup table, mathematical calculations satge of transformations, vector determination, calculation of duty cycle, and switching generation. At the end of process,Space Vector Sinusoidal Pulse Width Modulation (SVPWM) signal is used for drive the IGBT at power circuit. The using of dsPIC provides flexibility for system development towards a more complex control [2]..

## II. SPACE VECTOR MODULATION

A Space Vector Modulation (SVM) is an algorithm for controlling a pulse width modulation to generate alternating current waveform on a three-phase inverter. By using a SVM the inverter can be controlled to produce a sinusoidal waveform with variable on magnitude and frequency or well known as VVVF (Variable Voltage Variable Frequency) inverter.

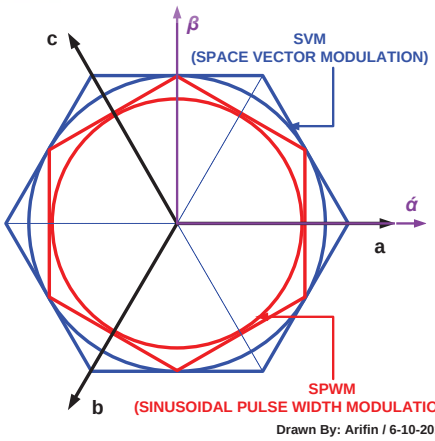


Figure 1. Comparison a maximum voltage in SVM and SPWM Methods

SVM using the method of taking all of 3 simultaneously modulating signal into a 2D reference coordinates (*ά-β* axis or in the complex form). Theoretically, SVM treats sinusoidal voltage amplitude as a vector or phasor rotating at a constant angular frequency. Amplitude vector is represented in the *ά-β* axis shows the real and imaginary.

Consideration from this project as shown in Figure 1. ,the locus of maximum voltage can be reached in SVM methods comparing with SPWM methods. With SVM technique the output voltage can reach the maximum values, it is greater than SPWM technique. In bellow will be axplained state of the art and study literature from this project [3]..

Six step- three phase- three legs inverter become the basis of main concept in SVM method. The topologies and switching configuration can be shown as bellow:

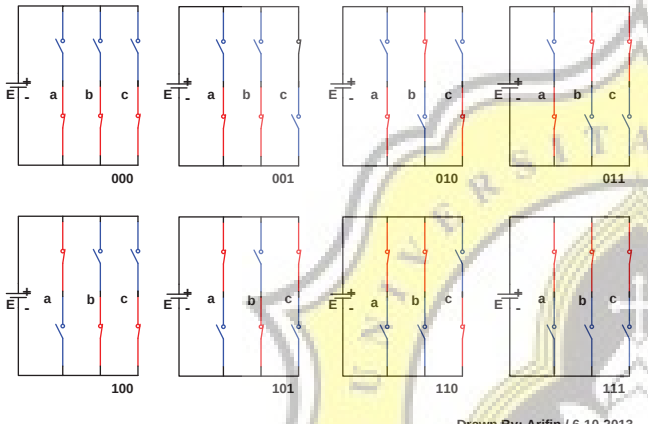


Figure 2. Topologies configuration of switching possibilities on 3 leg-3 phase inverter

TABLE I. SWITCHING CONFIGURATION OF THREE LEG VOLTAGE SOURCE INVERTER (VSI)

| Sap | Sbp | Scp | V ab | V bc | V ca | Vector | Note |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | E | 0 | -E | V1 | Active |
| 1 | 1 | 0 | 0 | E | -E | V2 | Active |
| 0 | 1 | 0 | -E | E | 0 | V3 | Active |
| 0 | 1 | 1 | -E | 0 | E | V4 | Active |
| 0 | 0 | 1 | 0 | -E | E | V5 | Active |
| 1 | 0 | 1 | E | -E | 0 | V6 | Active |
| 1 | 1 | 1 | 0 | 0 | 0 | V7 | Zero |
| 0 | 0 | 0 | 0 | 0 | 0 | V0 | Zero |

The figures and tables are presented the vectors that is formed by eighth switching configuration. In the active vectors in every condition there is only two phase-phase voltage is not be zero, and forming an angle of 60˚. The length of the voltage vector can be expressed as a voltage DC-link inverter:

$$|V| = \frac{2}{\sqrt{3}}E \qquad (1)$$

Note:
$|V|$ = magnitude of voltage vector
E = DC-link inverter

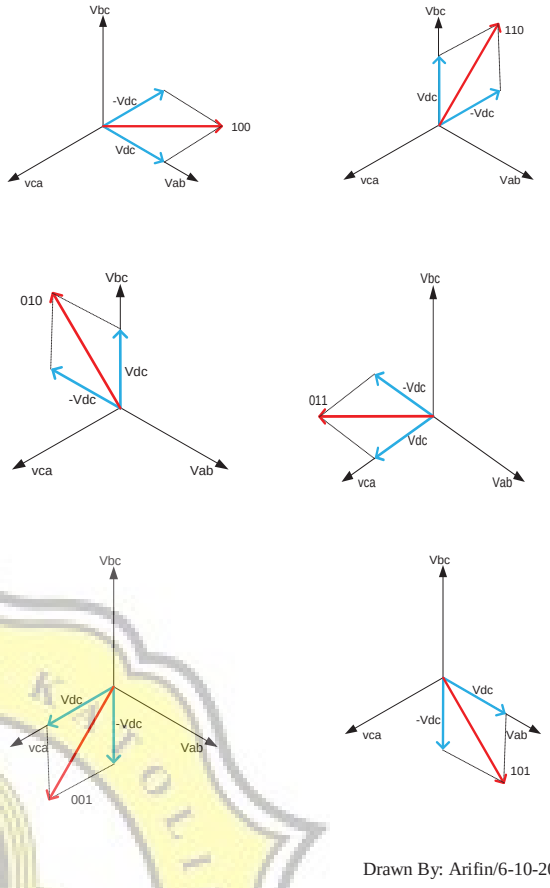


Figure 3. Forming a voltage vector from voltage phase

In balancing three phase system, the magnitude of current and voltage at a,b,c axist will fulfill an equation:

$$Va + Vb + Vc = 0 \; or \; Ia + Ib + Ic = 0 \qquad (2)$$

Voltage and current vector can be presented in two axis perpendicular (*ά-β* axis). With *Clarke* Transformation be obtained:

$$\begin{bmatrix} V\acute{\alpha} \\ V\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \qquad (3)$$

where is,

$$|V| = \sqrt{Va^2 + Vb^2} \; and \; \theta = arc\,tg\,\frac{Va}{Vb} \qquad (4)$$

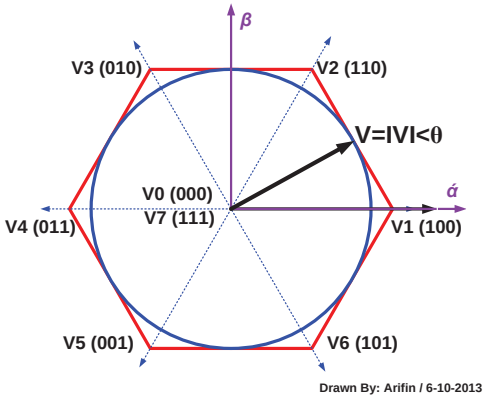


Figure 4. Voltage Vectors in *ά-β* axis

So, in the six step inverter in one period (360˚) only contains six voltage vector. If space between vector V1 and vector V2 divided into several time intervals and there are some voltage vectors, it will generate a better waveform. Thus this concepts known as SVM[4]..

## III. Implementation of Switching Table Based on Space Vector Modulation for Three Phase Inverter

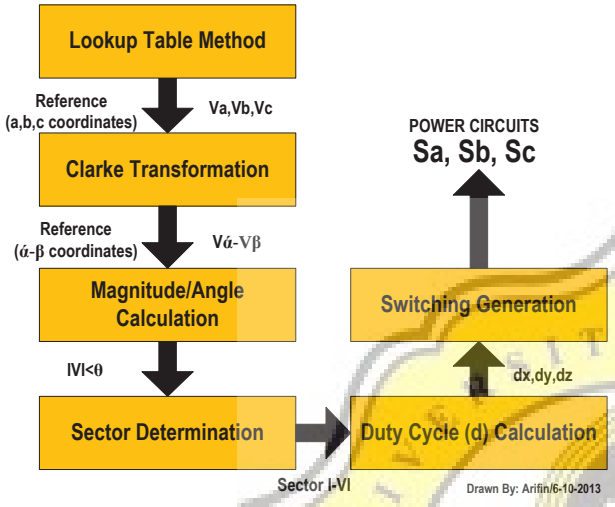


Figure 5. Space Vector Modulation Order Scheme

To give more detailed understanding an implementation from this project, will be presented as the figure above.

The Methods is used for generating a three phase reference signal (Va,Vb,Vc) is *Lookup Table* technique. Lookup Table method is a technique for inserting sample data array on memory of microprocessor, microcontroller, or other signal controller through array pointer. By take a sampling data will be generated an analog signal as desired/wave shaping. After this stage will be generated Va, Vb, Vc reference signal that is shifted 120 ˚ each other.

In the stage of Clarke Transformation with an equation which has been described previously will be generated V*á, Vβ* signal that is shifted 90 ˚ each other.

After that in Magnitude /Angle calculation will be generated two reference signal which is representated perameter of vector is magnitude and angle/direction of vector. For an example, a vector that is located between two active vector V1 and V2 . With a voltage vector synthesis be derivied a equation:

$$V = \frac{V1.tx}{Ts} + \frac{V2.ty}{Ts} \quad (5)$$

$$V = V1.dx + V2.dy$$

Note:
Ts = Sampling time
tx =Time duration PWM inverter estabilish V1 vector
ty =Time duration PWM inverter estabilish V2 vector

By using the value of index modulation which is a relationship between length of vector and DC-link inverter, be derivied a equation:

$$dx = \frac{2}{\sqrt{3}} m.sin\left(\frac{\pi}{3} - \theta\right)$$

$$dy = \frac{2}{\sqrt{3}} m.sin(\theta) \quad (6)$$

$$dx + dy < 1 \; thus \; we \; need \; dx + dy + dz = 1$$

Note:
dx, dy, dz = duty cycle

After Duty Cycle (d) Calculation get the value of dx, dy, and dz. The pattern is the basis of the switchin is executed in all sampling, in this case the amount of sampling in each vector will not affect the basic shape switching pattern. The change of each sampling pulse width dx, dy, dz/d0 is calculated based on the value of tx, ty, and tz/t0.

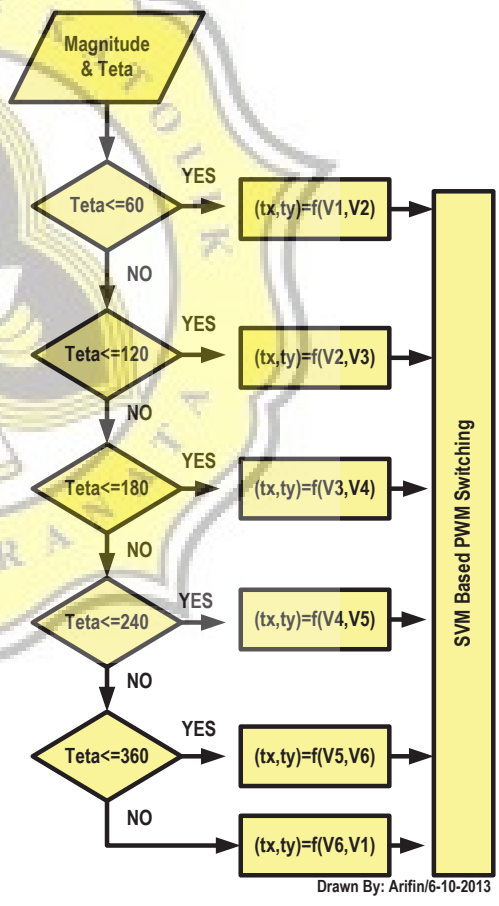


Figure 6. Flow Chart to Determine The Switching Table / Pattern of Space Vector Modulation

The input which is magnitude and phase angle from voltage vector reference should be determined in specified sector. Then performed the calculation of the duration of the voltage vector that flank each sector. By selecting the desired SVM techniques will be known the sequence switching each legs of inverter.

Hardware implementation of switching table based on space vector modulation for three phase inverter using dsPIC will be describe in bellow:

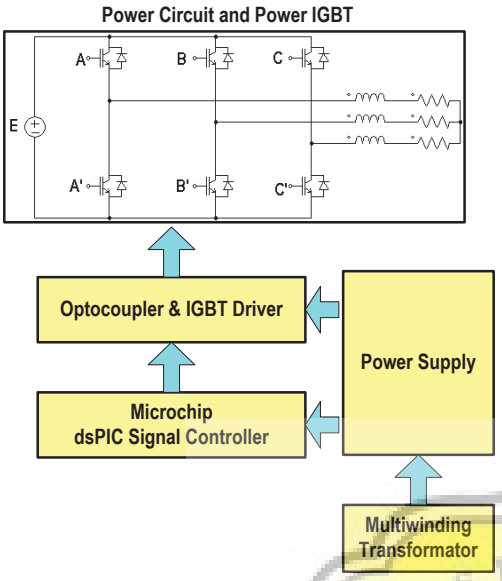


Figure 7. Block Hardware Design for SVM Implementation

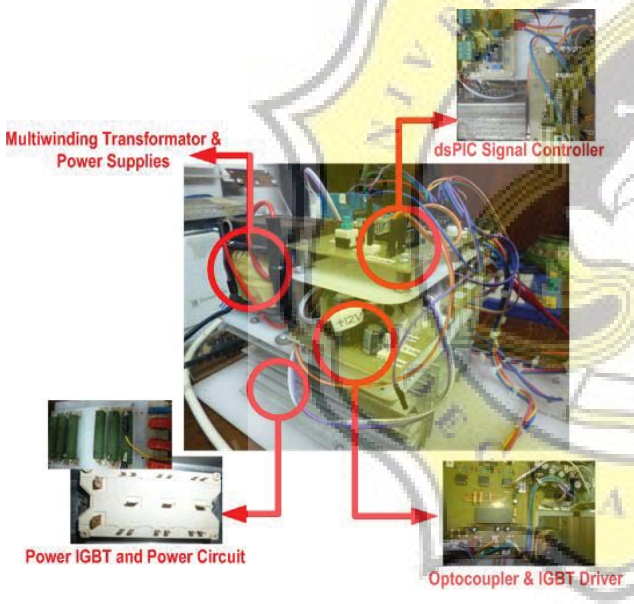


Figure 8. SVM Hardware Implementation and Components

Figure 9. Testing and Measuring Process

IGBT (Insulated Gate Bipolar Transistor) is used for static switch in power circuits. IGBT have wide range the nominal of current and voltage for implementation. For handle a SVM algorithms programming is used dsPIC 16 bits signal controller. This controller have a high performance for development SVM methods in more close loop complex control system.

## IV. RESULT AND EXPLANATION

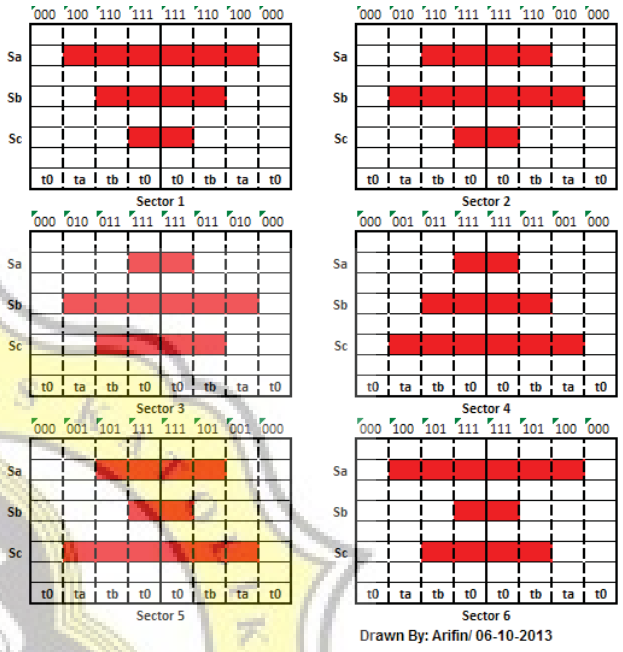


Figure 10. Output Signal on Each Vector of SVM Using Right Aligned Sequence Method

Each sector on space vector modulation have six different signal shapes to each other in static switch configuration. Changes in the signal shape of a sector to the next occur alternately and can be refined by increasing the number of sampling that is used.

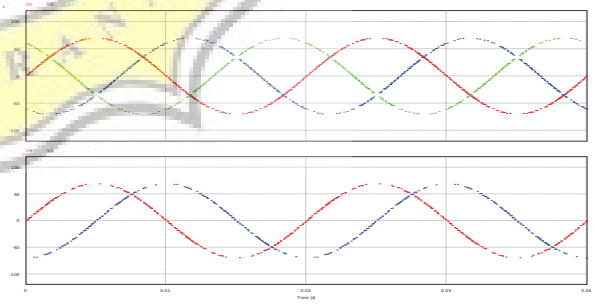

Figure 11. Reference Signal on a, b, c Coordinates and ά-β Coordinates

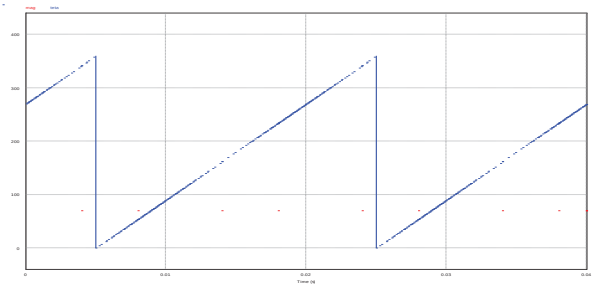

Figure 12. Reference Signal on Magnitude and Teta (Angle)